PRELIMINARY EVALUATION OF EXTRACTION WELL SYSTEMS

BASF WYNDOTTE CORPORATION

NORTH WORKS

WYANDOTTE, MICHIGAN

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Hydrogeologic investigations conducted at the BASF Wyandotte Corporation (BWC) North Works by S. S. Papadopulos & Associates, Inc. (SSP&A) demonstrated that most ground water flowing under the site discharges into the Detroit River and into the City of Wyandotte sewer system (SSP&A, 1984). As shown on Figure 1, discharge into the Detroit River occurs either directly, by diffused flow, or indirectly through discharge into a sump near the center of the site and a ditch in the northern part of the site, both of which lead to regulated outfalls into the Detroit River (Outfalls 001 and 003); discharge into the city sewer system occurs through a ditch in the southern part of the site.

Sampling by the Michigan Department of Natural Resources (DNR) and by BWC identified areas within the site where ground water is contaminated. The general location of these areas is shown on Figure 2, labeled as A, B, C and D. To prevent the discharge of ground water from these locations into the Detroit River and into the city sewer system, BWC requested SSP&A to evaluate and, where practical, design extraction well systems that would intercept contaminated ground water from these locations.

The hydrogeologic investigations conducted at the site (SSP&A, 1984) also demonstrated that the surficial materials underlying the site are non-homogeneous with extensive areas of low transmissivity. Therefore, a numerical, finite-difference simulation model (Trescott & Larson, 1976) of the surficial hydrogeologic system was developed to conduct an evaluation that considers a) the differences in the transmissivity of the surficial materials at different parts of the site, and b) the combined hydrologic effects of simultaneously operating potential extraction systems at different parts of the site.

The first step in evaluating potential extraction well systems was to determine the quantities of ground water that can be practically extracted at each of the four locations. The results of these preliminary evaluations led to the conclusion that extraction well systems are practical only at locations A, B and C. Because of the low transmissivities at the vicinity of location D (see SSP&A, 1984, Figure 13), an extraction system at this location would have a total extraction rate of less than 1.2 gpm with the discharge of individual wells being less than 0.2 gpm. Also, as it will be demonstrated below, the ground-water flow conditions that would result from the operation of extraction systems only at locations A, B and C are not significantly different than those resulting from extraction well systems at all four locations.

Figure 3 shows the predicted steady-state water table configuration with extraction systems operating at locations A, B and C. Most ground water in the vicinity of location D, presently discharging into the sump leading to Outfall 003 (see Figure 1), would be diverted by the extraction system at location B. Closer to the Detroit River, ground water from location D continues to discharge into the river by diffused flow. Flow through the affected area discharges along a river front of about 850 feet, shown as

Segment D on Figure 3. The average gradient of the water table near this discharge area is 0.0173 ft/ft. Using a conservative value of 14 ft^2/d for the transmissivity in this area, a value which is 40% larger than the 10 ft^2/d used in previous estimates (see SSP&A, 1984, table on p. 20), diffused discharge into the Detroit River through Segment D is calculated to be less than 1.1 gpm under the conditions depicted on Figure 3.

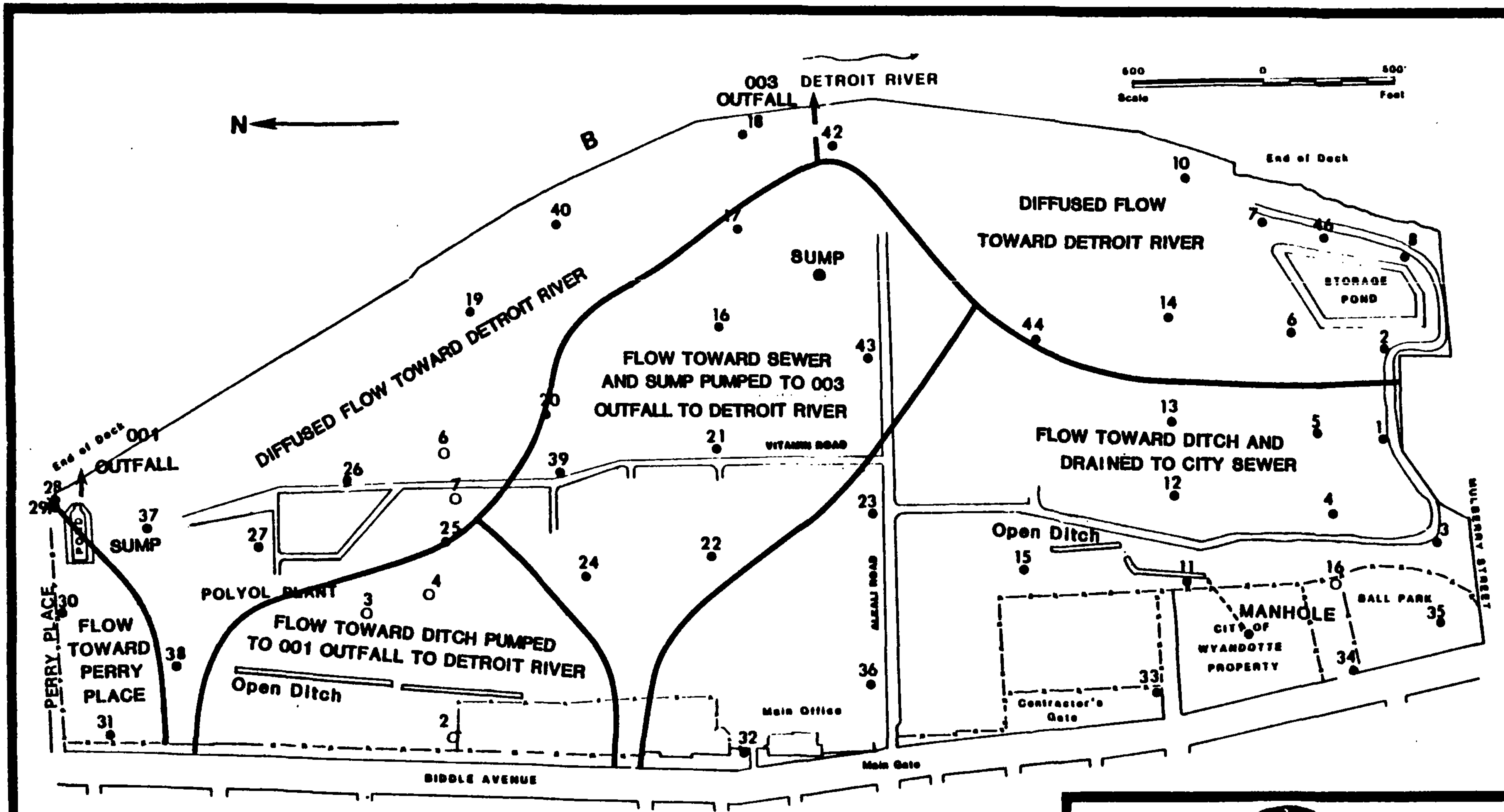
Figure 4 shows the predicted steady-state water table configuration with extraction well systems at all four locations (A, B, C and D). Under these conditions, diffused discharge into the Detroit River through Segment D is reduced only by 0.2 gpm (from 1.1 to 0.9 gpm). Thus, of the total discharge of 1.2 gpm that could be obtained from an extraction system at location D, only 0.2 gpm would be derived from the diversion of diffused flow into the river through Segment D. Most of the remaining discharge from this extraction system would be derived from ground water that, in absence of this system, would have been diverted by the extraction system at location B (see Figure 3).

Based on these findings, extraction well systems were designed for locations A, B and C.

References

S. S. Papadopulos & Associates, Inc., Rate and direction of ground-water flow at the North Works - BASF Wyandotte Corporation, Wyandotte, Michigan, Volume I, Main Report, December 1984.

Trescott, P. C., and S. P. Larson, Supplement to open-file report 75-438; Documentation of finite-difference model for simulation of three-dimensional ground-water flow: U.S. Geological Survey Open-file Report 76-591, 21 p., 1976.



LEGEND

12● New observation well P-12-N

3○ Existing observation well DNR 3

—— Boundary between different discharge areas

NOTE : ADAPTED FROM FIGURE 11 , SSP&A, 1984.

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FIGURE 1
GROUND-WATER FLOW DIRECTIONS BASED ON TIME-AVERAGED WATER LEVELS

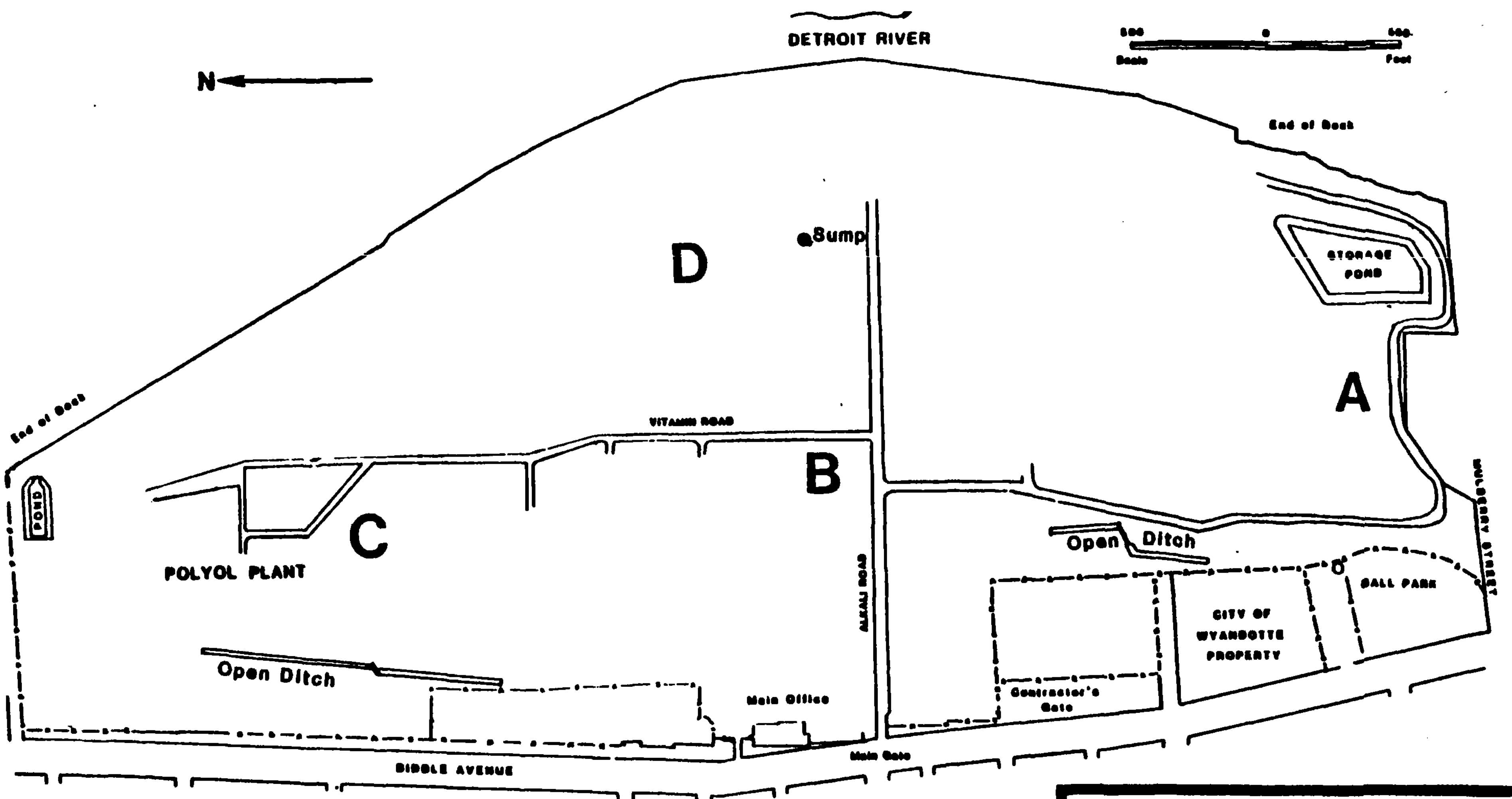

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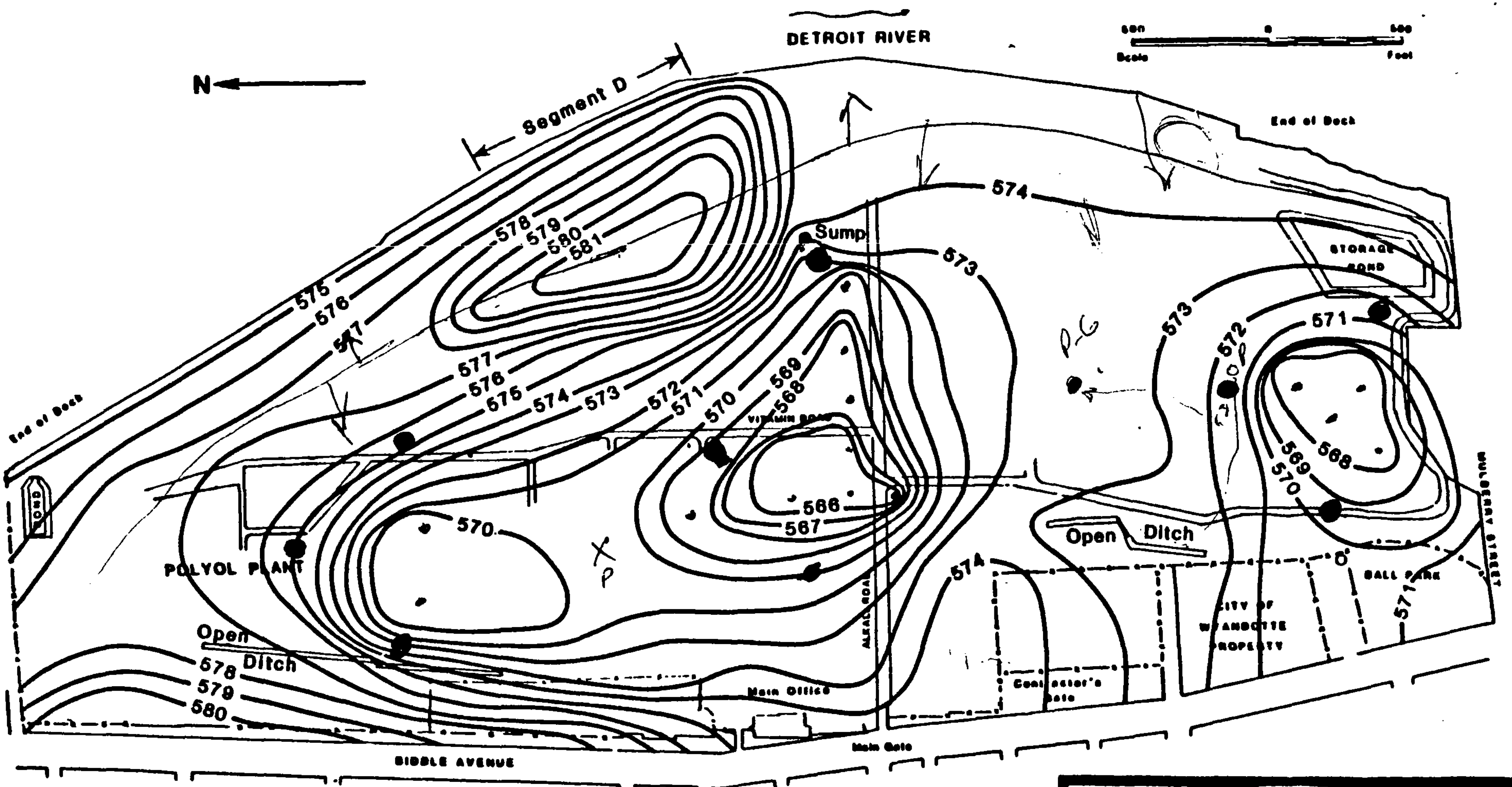
FIGURE 2
LOCATIONS EVALUATED
FOR GROUND-WATER
EXTRACTION



LEGEND

—570— Contour on predicted water table in feet (USC & GSD)

NOTE : Average mean daily stage of Detroit River assumed to be 574.94 (USC & GSD) based on Dec. 1,1983 – Oct. 31,1984 data at the Oak Street Gage, Wyandotte

$\Sigma^2\Pi$

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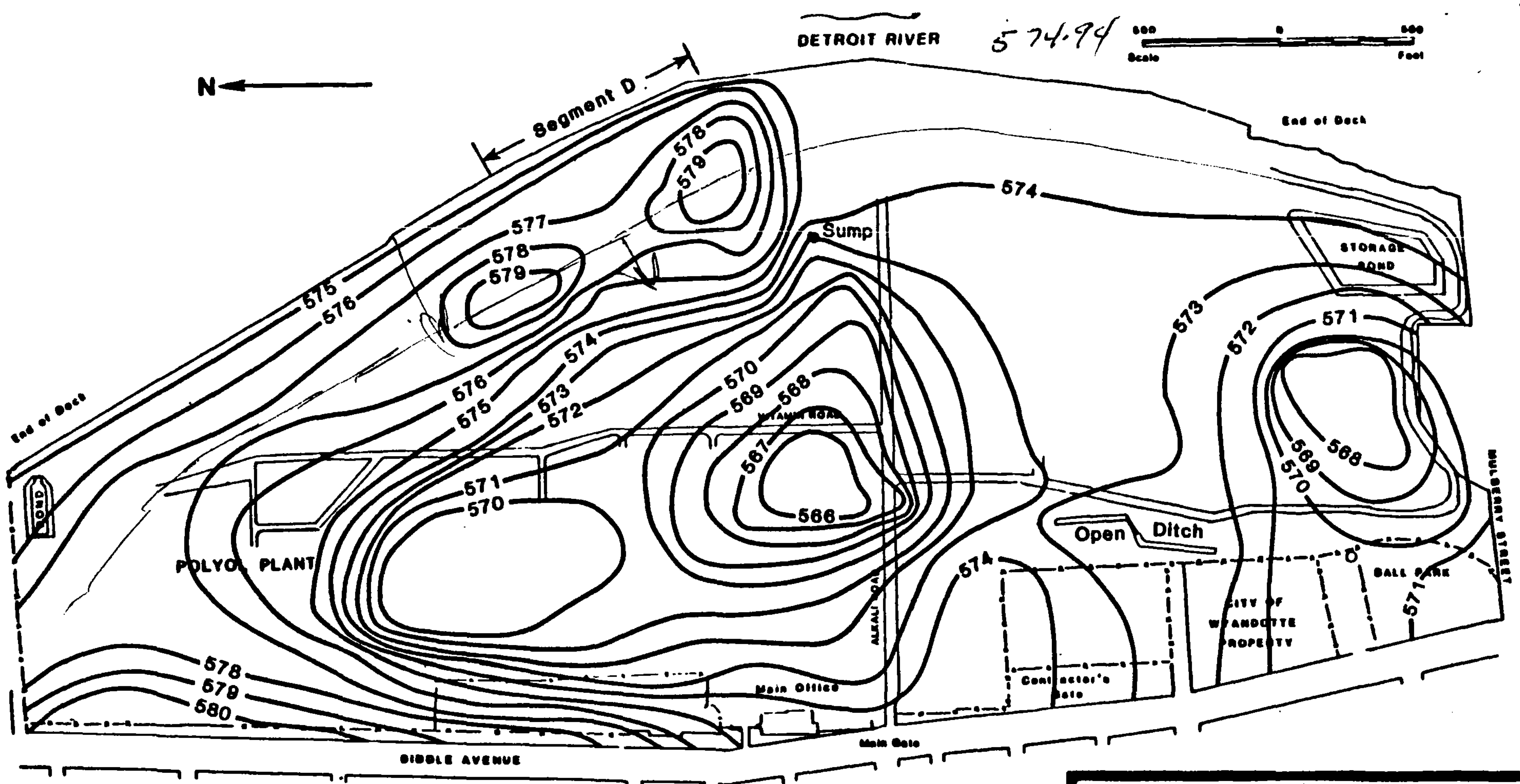
FIGURE 3
PREDICTED AVERAGE WATER TABLE DURING OPERATION OF EXTRACTION SYSTEMS AT LOCATION A, B AND C



LEGEND

—570— Contour on predicted water table in feet (USC & GSD)

NOTE : Average mean daily stage of Detroit River assumed to be 574.94 (USC & GSD) based on Dec. 1,1983 – Oct. 31,1984 data at the Oak Street Gage, Wyandotte

$\Sigma^2\Pi$

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FIGURE 4
PREDICTED AVERAGE WATER TABLE DURING OPERATION OF EXTRACTION SYSTEMS AT LOCATION A, B, C AND D

TABLE 7

WATER BALANCE

Water Balance Factor	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1) Precipitation (P)	1.91	1.73	2.47	3.22	3.31	3.42	3.10	3.28	2.16	2.48	2.32	2.27	31.7
2) Coefficient of Surface Runoff (C)	0.0	0.03	0.50	2.14	4.20	6.60	7.42	6.52	4.54	2.47	0.67	0.05	35.1
3) Surface Runoff R/O	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
4) Infiltration (I = P-R/O	0.57	0.52	0.74	0.97	0.99	1.03	0.93	0.98	0.65	0.74	0.70	0.68	9.5
5) Potention Evaportranspiration (PET)	1.34	1.21	1.73	2.25	2.32	2.39	2.17	2.30	1.51	1.74	1.62	1.59	22.2
6) I - PET	1.34	1.18	1.23	0.11	-1.88	-4.21	-5.25	-4.22	-3.03	-0.73	0.95	1.54	-13.0
7) $\sum_1^i$ Neg(I - PET)				(-0.03)	-1.91	-6.12	-11.4	-15.6	-18.6	+19.4			-
8) Soil Moisture Storage (ST)	2.00	2.00	2.00	1.97	.0.72	0.08	0.03	0.03	0.03	0.03	0.98	2.00	-
9) ΔST	0.00	0.00	0.00	-0.03	-1.25	-0.64	-0.05	0.00	0.00	0.00	0.95	1.02	0.0
10) Actual Evapotranspiration (AET)	0.0	0.03	0.50	2.28	3.57	3.03	2.22	2.30	1.51	1.74	0.67	0.05	
11) Percolation (PERC)	1.34	1.18	1.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.52	4.3

Notes

3) R/O = C(P)

4) I = P - R/O

11) PERC = P - R/O - ΔST - AET

All values, except the dimensionless surface runoff coefficient, are expressed in inches.

Soil moisture storage values (ST in line 8) are determined from Thornthwaite's soil moisture retention table (2 inch water holding capacity of soil root zone) using the summation values of negative I - PET (line 7) starting in April. After the soil moisture storage for each of the months with negative values of I - PET has been determined from the retention table, the positive values of I - PET (representing additions of moisture to the soil) are added to the previous month's ST values. No ST value can exceed soil moisture storage at field capacity, i.e., 2 inches. Any excess of I - PET above the maximum ST value becomes percolation or ground water recharge.

The Δ ST (line 9) represents the change in soil moisture from month to month.

Actual evapotranspiration (AET in line 10) represents the actual amount of water loss to the atmosphere during a given month. For those months where I - PET is positive (November through March), the rate of evapotranspiration is not limited by moisture availability, and actual is equal to potential evapotranspiration. For those months where I - PET is negative, soil moisture is below field capacity. The rate of actual evapotranspiration is limited by the soil moisture availability and is calculated from the formula : $AET = I - \Delta ST$.

Percolation values (line 11) are calculated monthly by solving the water balance equation: $PERC = P - R/O - \Delta ST - AET$. After the soil moisture storage reaches its maximum, any excess infiltration becomes percolation or ground water recharge. Therefore, significant ground water recharge will occur only during those months when I exceeds PET (i.e., I - PET is positive) and the soil moisture exceeds its maximum.

For the assumptions of the water balance at Wyandotte, Michigan, Table 7 shows a net ground water recharge during the months of December through March, which amounts to 4.3 inches of the total normal annual rainfall of 31.7 inches.

The ground water recharge calculated by the water balance methodology represents theoretical net ground water recharge to the ground water system in the area of the site during an average precipitation year. It does not fully represent local recharge from a wet year to the shallow perched flow system trapped in the fill and soil deposits, which is controlled by infiltration. The calculated ground water recharge is, therefore, thought to be more representative of a properly graded site for a normal precipitation year. Actual recharge rates on this site for the current year could exceed the calculated value of 4.3 inches. However, large amounts of recharge would leave relatively quickly through the numerous outflow mechanisms described in the following subsection, Stormwater.

Precipitation and potential evapotranspiration are the two factors with the fewest sources of error in computing the monthly water balance for the site. Both are dependent on climatological data collected for a 30-year period of time at the Detroit Airport, 10 miles away.

The critical surface runoff and soil moisture factors are estimated from site observations and guidelines in Thornthwaite's water balance methodology. Table 8 presents a sensitivity analysis for these factors and their impact on percolation. There is a greater potential for ground water recharge or percolation with lower runoff and soil moisture storage capacity values.

Stormwater

Several sets of observations were made on the site immediately following rainstorms. During May, a 0.37 inch rainstorm over a two-hour period produced very little surface runoff. During June, a 1.02 inch rainstorm over a one-hour period produced large quantities of stormwater runoff. This storm was equal to the one year one hour rainfall storm.[12] During both storms, depression accumulation of water on the site was significant.

The majority of water from the May storm infiltrated into the soil on the site or formed shallow puddles. Very little water was observed to have immediately entered the drainage system of the area. However, the next day seeps along Central Avenue had noticeably increased in flow to the area's external drainage system. This suggests a delayed response from an interflow component of direct runoff and is consistent with the perched water table described previously. It is likely that the stormwater followed a relatively short path in the permeable material above the shallow ground water flow system and quickly appeared at the water outflow areas. Very little mixing occurred between this interflow water and the resident perched water within the fill materials.

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20 March 1981

Mr. Keith Fry, Director
Corporate Environmental Protection
BASF Wyandotte
100 Cherry Hill Road
P.O. Box 181
Parsippany, NJ 07054

Dear Keith:

We are pleased to submit herein ten copies of our final report, "Hydrogeology, Hydrology, and Water Quality at the Central Avenue Site, Wyandotte, Michigan". We have retained one copy of the final report and relevant supporting data in our files.

We have greatly enjoyed the opportunity of working with you on this project. We look forward to providing you with hydrogeologic and engineering services on future problems that may arise in the environmental area.

Respectfully submitted,

Ronald A. Landon

Ronald A. Landon, P.G.
Principal

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Attach.